ATTENUATION RELATION OF JMA INTENSITY BASED ON JMA-87-TYPE ACCELEROMETER RECORDS

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Attenuation relations of earthquake ground motion are used for seismic hazard and risk analyses and therefore it is necessary to develop them based on observed data. Recently the JMA intensity scale was revised and large number of seismometers measuring the intensity were deployed throughout Japan. In this study, the new JMA intensity scales are calculated for the strong ground motion data set with 2,166 three-component records obtained by the JMA-87-type accelerometers. Then an attenuation relationship for the JMA Intensity is developed and examples are presented.

Key Words : *Attenuation relaton, strong groundmotion, JMA intensity, JMA-87-type accelerometer.*

1. INTRODUCTION

Development of earthquake monitoring and early damage assessment systems[1)] becomes quite popular in Japan after the 1995 Hyogoken-Nanbu Earthquake. In these systems, the peak ground acceleration (PGA), peak ground velocity (PGV), or the spectrum intensity (SI) are used as the index representing the ground motion severity.

Since 1987, the JMA has been deploying JMA-87-type accelerometers throughout Japan. The network started with 76 stations. In 1993 and 1994, several damaging earthquakes occurred in northern Japan. Hence, mainly for early tsunami warning, the number of accelerometer stations was increased to 268. After the Hyogoken-Nanbu Earthquake, the number of JMA's stations was further increased to 574. Once an earthquake occurs, intensities (calculated automatically on site) at the 574 stations are collected immediately through JMA's telecommunication system.

Recently the Fire Defense Agency (FDA) also ventured upon a project to deploy one seismometer measuring JMA intensity in each municipality (3,255 in total). When this network is completed, the distribution of intensity due to an earthquake can be estimated even in case of a very localized event. The FDA and the JMA will also exchange their collected data. Disaster management agencies will use these information for identifying affected areas and preparing for crisis management.

Since intensity data are most promptly obtained and largest in number, the JMA intensity will be used more frequently in damage assessments. Considering these situations, an attenuation relationship is developed in this study using the data recorded by JMA-87-type accelerometers.

2. EARTHQUAKE DATA

The acceleration records used in this study consist of 2,166 three-component sets from 387 events. These data were recorded by JMA-87-type accelerometers at 76 free field sites from August 1, 1988 to December 31, 1993. The data set includes records for some major events, such as the Kushiro-Oki Earthquake (M=7.8 in JMA scale) on January 15, 1993, and the Hokkaido-Nansei-Oki Earthquake (M=7.8) on July 12, 1993. Records with peak ground accelerations (PGA) less than 1.0 cm/s^2 in one horizontal component were omitted. Events whose focal depths were zero or greater than 200 km were also excluded from the analysis. The records are mostly far-field ones since the records from the 1995 Hyogoken-Nanbu Earthquake are not included. Information regarding the JMA stations, such as location, soil type, and number of records for each station, is listed in Molas and Yamazaki[2].

3. NEW JMA INTENSITY

The JMA seismic intensity scale was revised recently[3]. First, the Fourier transform is applied for the selected time window for three-component acceleration time histories. Then a band-pass filter is applied in the frequency domain. After taking the inverse Fourier transform, a vectorial composition of the three-components is made in the time domain. Considering an acceleration value a_0 having total duration τ satisfying $\tau(a_0) \geq 0.3$ sec, the new JMA seismic intensity I is obtained by

$$I = 2.0 \log a_0 + 0.94 \qquad (1)$$

Figure 1 shows the relationship between the JMA magnitude and the calculated intensity for the current data set. The largest intensity in the data set is 6.4, which is recorded at the Kushiro station during the Kushiro-Oki Earthquake. The other intensity data are distributed between 5.5 and 0. Note that some intensity values are less than 0 because of the logarithmic function represented by Eq. (1).

Applying a linear regression to the JMA intensity and PGA data sets, a new linear relation is derived for the current data set as shown in Fig. 2 and written by the following equation:

$$I = 1.84 \log PGA + 0.26 \qquad \sigma=0.291 \qquad (2)$$

where PGA is the larger of two horizontal components and σ is the standard deviation of the relationship. In Fig. 2, two other equations between PGA and JMA intensity are plotted. Tong and Yamazaki[4] derived the following relationship based on 205 three-component sets from the 1995 Hyogoken-Nanbu (76 records), the 1994 Northridge (27), the 1993 Kushiro-Oki, the 1993 Hokkaido-Nansei-Oki, the 1994 Hokkaido-Toho-Oki, the 1994 Sanriku-Haruka-Oki Earthquakes, etc.

$$I = 1.89 \log PGA + 0.59 \qquad \sigma=0.281 \qquad (3)$$

The difference between Eqs. (2) and (3) comes from the difference of the two data sets: the data of this study have mostly small intensity values while Tong and Yamazaki's data set is well distributed including data from non-JMA stations in Japan and from the United States. In Fig. 2, the empirical relation by Kawasumi (1943) is also plotted.

$$I_k = 2.0 \log PGA + 0.7 \qquad (4)$$

Considering the improved sensitivity of recent accelerometers in the high frequency range, it may be reasonable that the recent PGA corresponds to smaller intensity.

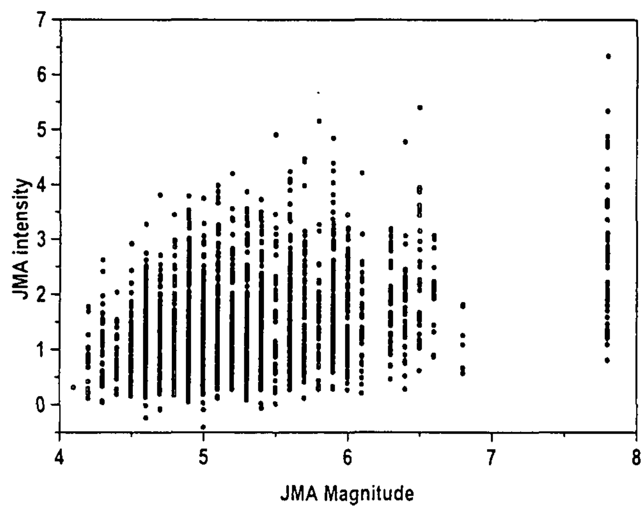


Fig. 1 Distribution of the JMA intensity with the JMA magnitude for the current data set

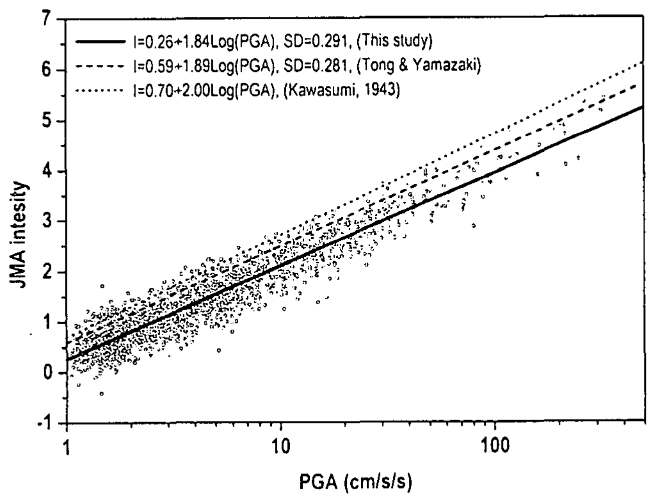


Fig. 2 Relationship between the JMA intensity and PGA

4. ATTENUATION MODEL

The attenuation model for the JMA intensity in this study is given by

$$I = b_0 + b_1 M + b_2 r + b_3 \log_{10} r + b_4 h + c_i \quad (5)$$

where I is the JMA intensity, M is the JMA magnitude, r is the closest distance to the fault rupture, h is the source depth, c_i is the coefficients representing local site effect of the i-th station. Note that the mean value of all the station coefficients is zero. b_i's are the coefficients to be determined. The term $b_2 r$ represents anelastic attenuation and the term $b_3 \log r$ represents geometric spreading.

Equation (5) is basically same as those for PGA and PGV[2] except for the fact that the log scale is used for those indices. Considering the definition of the intensity (Eq. 1), the geometric spreading constant b_3 is unconstrained, or if constrained, it is set to be -2, corresponding to a spherical spreading from a point source. Intensity attenuation models in other areas[5),6)] may be useful to discuss adequacy of the current model.

The three-stages iterative partial regression method[2] is used to obtain the coefficients in Eq. (5). The first step determines the coefficients by one-stage linear regression. These coefficients are used as initial estimates. The second and third-steps are similar to the two-stage regression procedure of Joyner and Boore[7].

5. RESULTS AND DISCUSSIONS

Figure 3 indicates the station coefficient obtained for the 76 JMA stations. Similar as the station coefficient for PGA, the station coefficient for the intensity is the largest for Kushiro and the smallest for Matsushiro. The weighted mean (with the number of records for each station used as weights) is 0.197 for the intensity.

Figure 4 shows the predicted JMA intensity with respect to the distance for depth of 10 km and magnitudes of 6.0 (dot line), 7.0 (dash line) and 8.0 (solid line). Although the mean of the residuals for all the records is zero, the mean residual for each station is not zero. Hence, the weighted mean station coefficients (0.197) is used in the plot. The maximum predicted intensity for the magnitude 8.0 event is about 6.0 at the shortest distance of 10 km. This intensity value looks rather small. However, variability of station coefficient (see Fig. 3) indicates that depending on sites, the predicted intensity becomes much larger (as large as about 0.9 for Kushiro).

It should be noted that since the current data set does not include near-source records such as those in the Hyogoken-Nanbu Earthquake, the near-source saturation effect is not considered in the attenuation model. Hence, the application of the current model to very near-fields should be avoided. Note that the predicted JMA intensity increases as the depth decreases because of the positive sign for b_4.

The proposed attenuation model is examined in Fig. 5 for two large earthquakes in the data set: the 1993 Kushiro-Oki and the 1993 Hokkaido-Nansei-Oki earthquakes. In the figure, the solid line represents the predicted attenuation relation for M=7.8 and the source depths, open circles are intensities calculated from the records, and plus symbols are adjusted intensities removing site effects (station coefficients). For both events, the adjusted intensities are much closer to the predicted curves than the recorded ones. Even though the same magnitude, the Kushiro-Oki Earthquake generates larger seismic intensities than the Hokkaido-Nansei-Oki Earthquake as seen similarly for PGA[2].

After compiling this data set, the number of available JMA data became almost double, including strong events such as the Hokkaido-Toho-Oki, Sanriku-Haruka-Oki, and Hyogoken-Nanbu earthquakes. Recently, the strong motion data other than JMA, such as K-Net of NIED, are also available. Hence, the attenuation relation for the JMA intensity should be further upgraded introducing these data and near-source effects.

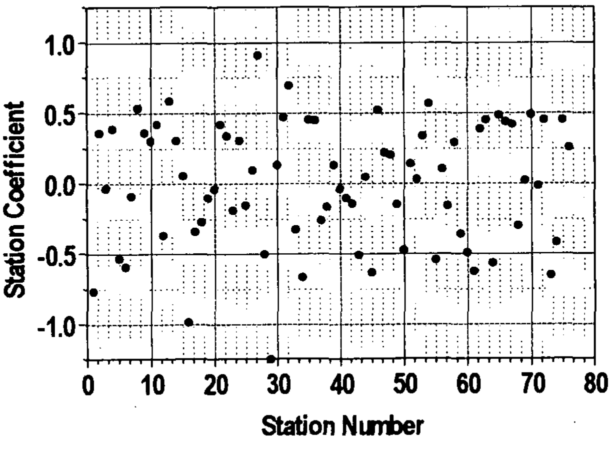


Fig. 3 Station coefficients for JMA intensity for 76 JMA recording stations used in this study.

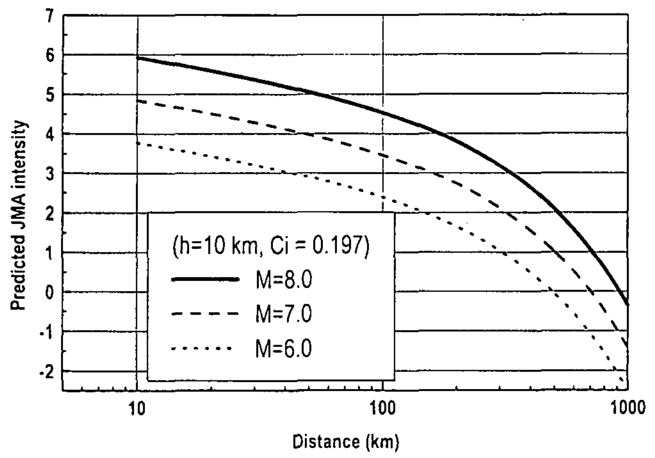
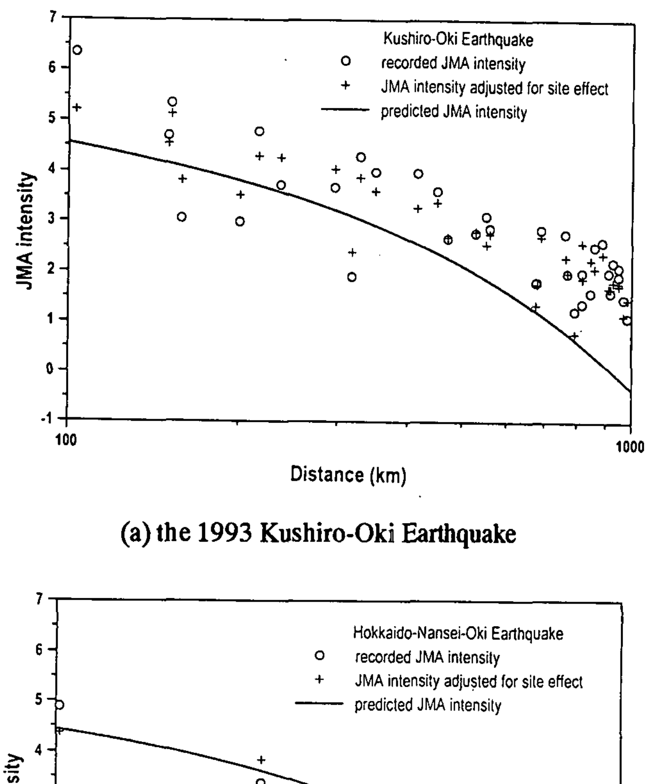
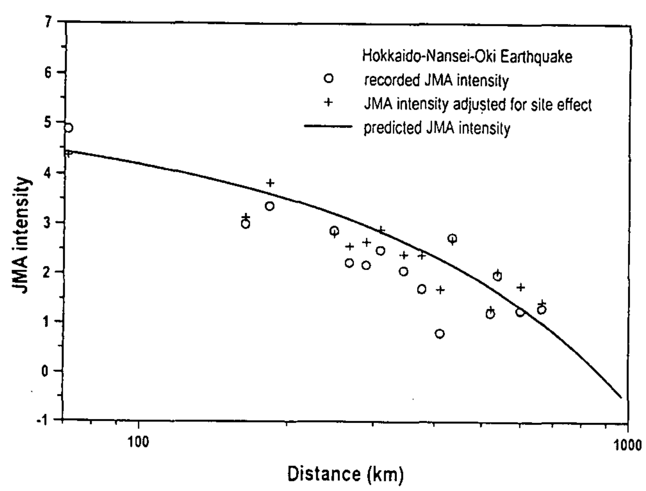


Fig. 4 Predicted JMA intensity for JMA magnitudes of 6.0, 7.0, and 8.0 for depth of 10 km with mean weighted station coefficient 0.197



(a) the 1993 Kushiro-Oki Earthquake



(b) the 1993 Hokkaido-Nansei-Oki Earthquake

Fig. 5 Predicted JMA intensity by the attenuation relation compared with recorded intensities and adjusted recorded intensities in two large magnitude events

6. CONCLUSIONS

An attenuation relationship was developed for the new JMA seismic intensity using the 2,166 three-component records from the JMA-87-type accelerometers. The attenuation model proposed by Molas and Yamazaki for the peak ground acceleration and velocity was employed for the intensity attenuation.

The three-stage iterative regression analysis gave the coefficients for the intensity. Local site effects is considered by the station coefficient. The obtained attenuation model was examined by recorded data in two large magnitude events.

Considering rapid increase of strong motion records in Japan, we are now developing a revised version of the model proposed here. The result of the continuing study will be presented soon elsewhere.

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